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FAST FRAMING CCD CAMERA SYSTEM FOR HIGH FREQUENCY HYPERSONIC FLUID DIAGNOSTICS

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The Fast Framing CCD Camera System designed under this contract provides high speed imaging via a solid state image sensor. The camera operates in a burst mode, capturing images at frame rates up to 1,000,000 frames per second, and retaining in the image sensor's memory the last 32 images. Several operating modes provide flexibility in triggering, and a focus mode allows for focusing and aligning external optics. The user interface for controlling the camera is provided via the Netscape Communicator browser, which also makes remote operation of the camera easy to accomplish. The user can change frame rate, and set up triggering conditions, then capture images and display them, all in the same browser window. An on-line user manual can also be accessed from the browser which provides descriptions ans setup of operating modes and trigger conditions.

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FINAL REPORT

Fast Framing CCD Camera System for High Frequency Hypersonic Fluid Diagnostics

F33615-94-C-3003

MAY 1998

Final Report

Contract: F33615-94-C-3003

"Fast Framing CCD Camera System for High Frequency Hypersonic Fluid Diagnostics"

Project Summary

The Fast Framing CCD Camera System designed under this contract provides high speed imaging via a solid state image sensor. The camera operates in a burst mode, capturing images at frame rates up to 1,000,000 frames per second, and retaining in the image sensor's memory the last 32 images. Several operating modes provide flexibility in triggering, and a focus mode allows for focusing and aligning external optics. The user interface for controlling the camera is provided via the Netscape Communicator browser, which also makes remote operation of the camera easy to accomplish. The user can change frame rate, and set up triggering conditions, then capture images and display them, all in the same browser window. An on-line user manual can also be accessed from the browser which provides descriptions and setup of operating modes and trigger conditions.

General Description

The Princeton Scientific Instruments (PSI) Ultra Fast Framing Camera is a very high speed solid state imaging system which uses a PSI patented CCD image sensor. Table 1 gives details of the sensor.

The CCD image sensor provides an on-chip storage array for 32 images, which can be exposed at burst rates of up to 1 million frames per second. Figure 1 is a schematic diagram showing 4 pixels of the CCD. Charge from a photodetector is shifted out serially for each of 4 frames, then a vertical shift moves the entire row. Stored charge from older images is dumped and replaced by charge from new images. An external trigger is used to stop the image capture, and the entire storage area is read out in approximately 10 seconds.

The 3 main components of the camera are the Camera Head, Control Chassis, and Data Acquisition Computer as shown in Figure 2.

The Camera Head contains the CCD and a thermo-electric cooler in a sealed enclosure. A mechanical shutter and a Ferro-Electric Liquid Crystal Shutter are incorporated in front of the CCD, but outside of the sealed enclosure. Two shutters are used to provide the high speed response of the electronic shutter, and the ultimate attenuation of the mechanical shutter during the readout. A Nikon lens is mounted in front of the shutters.

The Control Chassis contains the specialized timing and control electronics to operate the CCD chip. The user can control the frame rate, trigger mode, and other options via a graphical user interface (GUI) which uses the Netscape Communicator browser, through the Data Acquisition Computer. Clocking signals are sent to the Camera Head and video signals are returned to the Control Chassis. A video processing board amplifies the video signal and performs double correlated sampling to reduce noise and maximize dynamic range. The 2 video signals (one from each half) are digitized and sent to the Data Acquisition Computer. (Only one half is active on the Serial No. 01 camera.)

The Data Acquisition Computer receives the digital data from the Control Chassis and stores it in memory. Due to the nature of the CCD image storage, 1 line of data contains pixels from 4 different frames. As data is read into memory, it is "unscrambled" so that pixels from the same frame are stored together and in order, forming an image raster. The images are also written to the hard disk as 32 separate files. The result of the readout is 32 frames in memory available for immediate display on a video monitor and 32 stored frames which can be down-loaded to a ZIP disk or can be accessed via an Ethernet link.

Operation

The CCD is operated at -20 to -30 C to reduce dark current during the readout time. A thermo-electric cooler in the sealed enclosure of the Camera Head provides cooling of the CCD. A fan inside the head enclosure air cools the hot side. The mechanical and Ferro-Electric Liquid Crystal shutters are opened prior to exposure, and closed during readout on command from the Control Chassis.

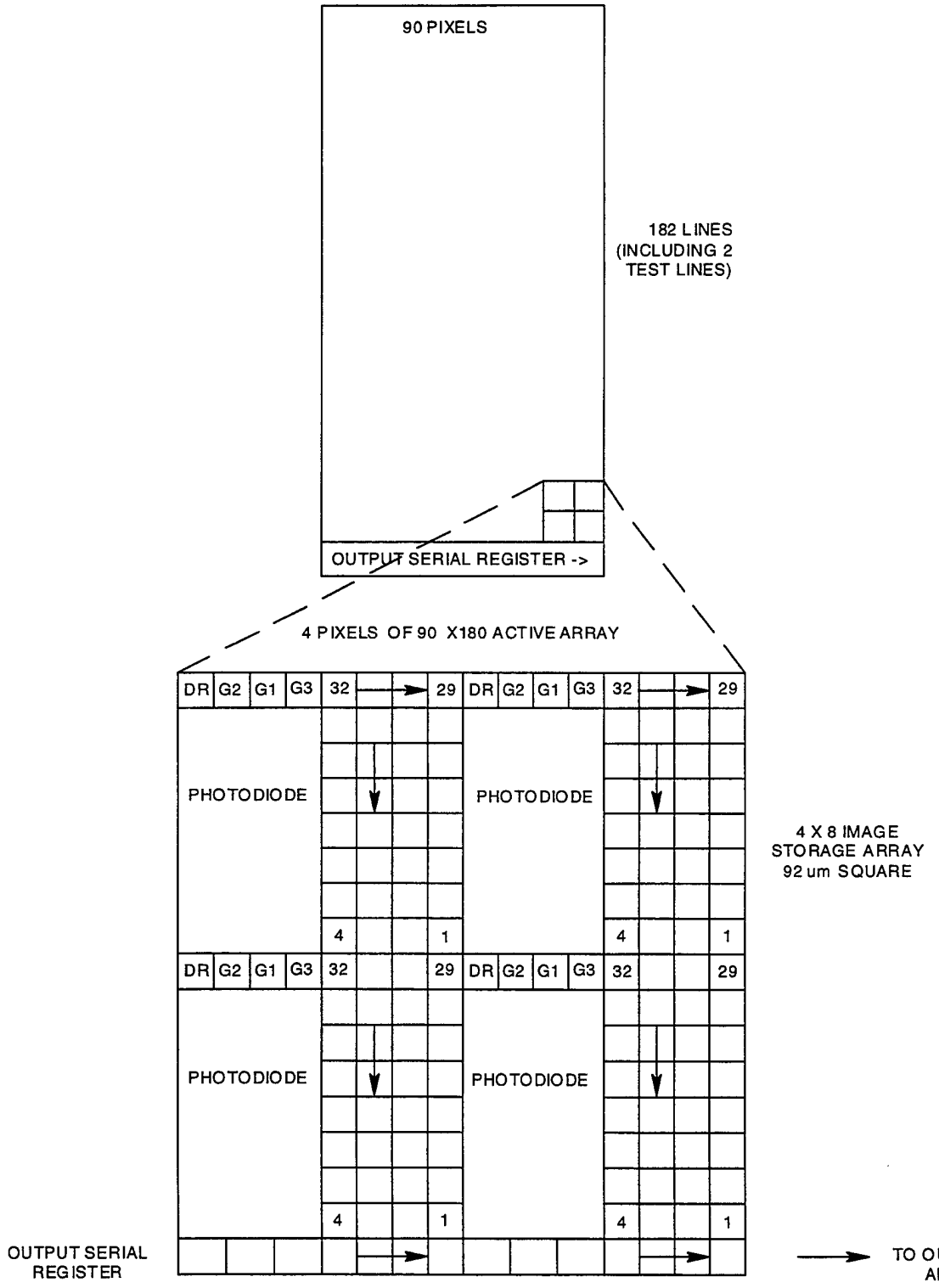
Frame rate is user selected. The camera can capture images in an internally triggered mode upon command from the keyboard, or in an externally triggered mode. Before trigger, the camera runs with the shutter open in a continuous erase/expose mode. In this mode all frames in the storage area are continually over-written with new images while old images are dumped. When a trigger is received, the overwriting is stopped. The result is that the most recent 32 frames are captured in the storage area. The shutters are closed and readout takes place as soon as the exposure is completed. The frames are given file names with a user supplied root name and consecutive numbers 1- 32 supplied automatically.

The computer monitor provides display of the images in memory. Images can be viewed sequentially in a "movie" mode, and images previously stored on the hard disk can be re-loaded into memory and displayed on the monitor. The digitized images can also be read by image processing software packages.

Table 1. Characteristics of CCD Image Sensor

Number of active pixels	90 x 180
Pixel size	92 um x 92 um
Optical Fill factor	34 %
Number of frame-storage CCD elements per pixel	32
Readout format	3-phase CCD elements
Saturation signal	17,000 (A/D units)
Qmax	64,000 (electrons/pixel)
Readout noise	65 (rms electrons/pixel)
Dynamic range	1000:1
Maximum frame rate	1 x 10E6 frames/sec; (1 uS/frame)
Integration time range	10 % to 100 % of frame time

FIGURE 1
PSI ULTRA FAST CAMERA CCD SCHEMATIC DIAGRAM



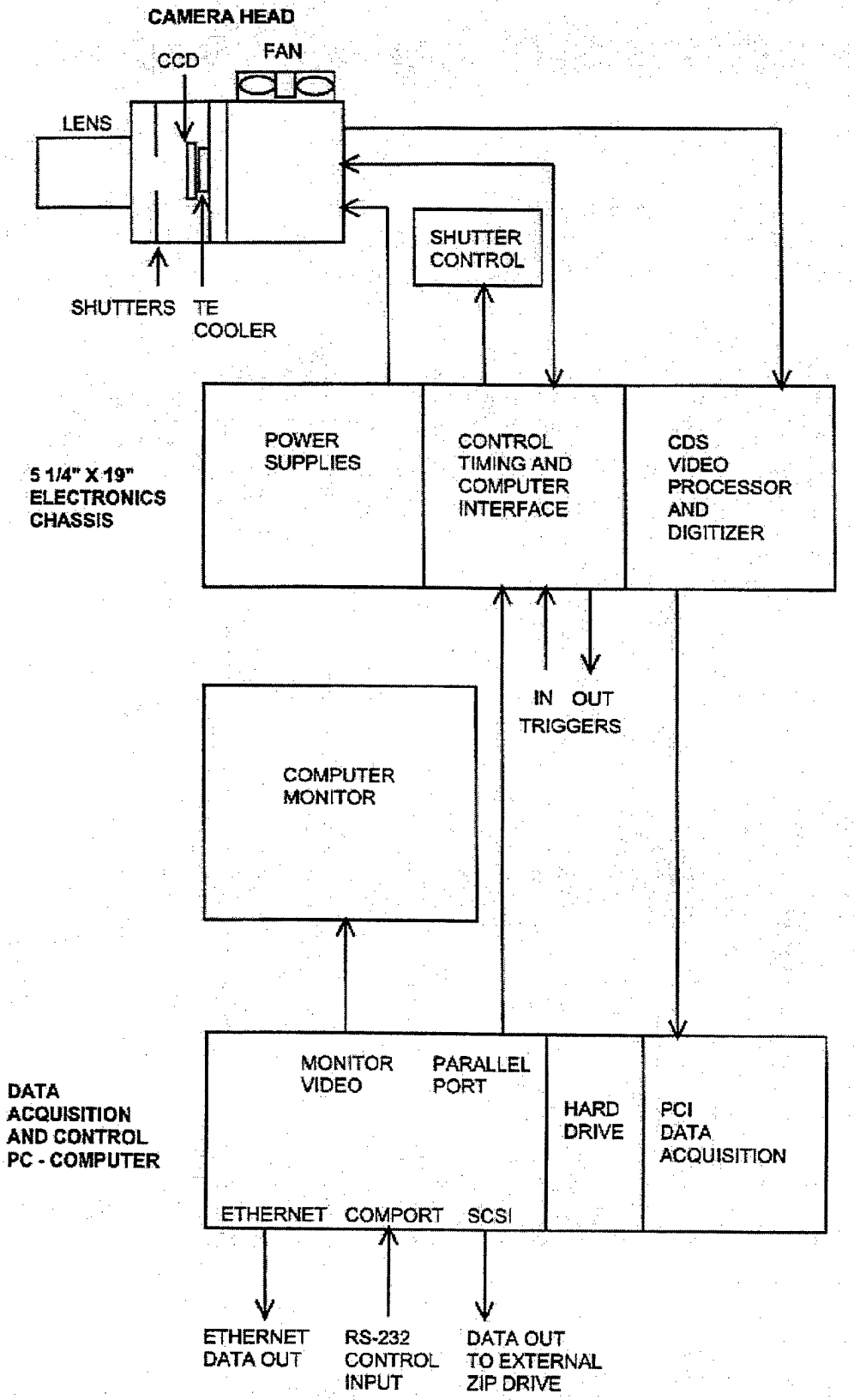


FIGURE 2. ULTRA FAST FRAMING CAMERA BLOCK DIAGRAM

FFCBKDC.DSF

Internal Hardware Operation

RAM based operation

The camera control architecture is RAM based. That is, the operating waveforms for the CCD are loaded into RAMs on the control board prior to running the camera. This allows very flexible operation compared to fixed patterns stored in ROM, and also permits user control of timing signals which can be output during operation. Because the entire operating sequence is loaded into RAM prior to operation, there is no dead time required to write new data to the RAM. A large FPGA device on the Control Board handles the address generation for the RAMs and other digital control functions.

Operating Modes

PrePost Trigger Mode

PrePost Trigger Mode is the image acquisition mode in which the camera free runs in a continuous loop until triggered. While running in the continuous Pre-trigger loop , new frames continually overwrite old frames. When the trigger is received, the camera will continue to run and acquire the user specified number of Post-trigger frames, then acquisition stops and readout begins.

The number of Post-trigger frames can vary from 0 to 4096 in multiples of 4. When the number is 0, all frames are acquired before the trigger during the Pre-trigger loop. When the number is from 4 to 28, the acquisition is divided between Pre-trigger and Post-trigger frames. When the number is 32 or more, all acquisition takes place after the trigger.

When the number of Post-trigger frames is greater than 32, the camera will delay acquisition after the trigger is received by a time equal to the number of frames greater than 32. For example: if the number of Post-trigger frames selected is 64, and the frame time is 10uSec, then the camera will delay for 32(extra frame times) x 10uSec = 320uSec before acquisition.

If External Trigger has been selected, and a trigger can not be supplied, then the Cancel Button must be used to break out of the acquisition mode.

In PrePost Mode the user can select Frame Rate, Integration Time, Triggering configuration, User Strobes and other options.

The trigger uncertainty in this mode is 0 to 4 frames. When a trigger is received, the frames of the current row in the storage array are completed before jumping to the Expose pattern. This is necessary to avoid losing Pre-Trigger frames.

Post Trigger Mode

Post Trigger Mode is the image acquisition mode in which the camera free runs in a continuous loop until triggered. While running in the continuous Pre-trigger loop, charge is continually

dumped preventing dark charge buildup. Pre-Trigger image acquisition is not available in this mode. When the trigger is received, the camera jumps to the Expose pattern and acquires the user specified number of Post-trigger frames, then acquisition stops and readout begins.

The number of Post-trigger frames can vary from 32 to 4096 in multiples of 4. When the number of Post-trigger frames is greater than 32, the camera will delay acquisition after the trigger is received by a time equal to the number of frames greater than 32. For example: if the number of Post-trigger frames selected is 64, and the frame time is 10uSec, then the camera will delay for 32(extra frame times) x 10uSec = 320uSec before acquisition.

If External Trigger has been selected, and a trigger can not be supplied, then the Cancel Button must be used to break out of the acquisition mode.

In Post Mode the user can select Frame Rate, Integration Time, Triggering configuration, User Strobes and other options.

The trigger uncertainty in this mode is 0 to 4 substates (0 to 0.4 frames). When a trigger is received, the frames of the current row in the storage array are skipped and the camera jumps to the Expose pattern. No Pre-Trigger frames are kept in this mode.

Multi TriggerMode

Multi Trigger Mode is the image acquisition mode in which the camera free runs in a continuous loop until a first trigger is received, then waits for subsequent triggers for each of the 32 frames. While running in the continuous Pre-trigger loop, charge is continually dumped preventing dark charge buildup. Pre-trigger image acquisition is not available in this mode. When the first trigger is received, the camera jumps to the expose pattern and waits for a trigger for each frame. One frame is exposed for each trigger at the user specified frame rate and integration time.

All 33 triggers must be received (first trigger + 32 frame triggers), or the camera will not readout the images. If all 33 triggers can not be supplied then the Cancel Button must be used to break out of the acquisition mode. The first trigger may be input on the same trigger channel as the 32 frame triggers, or a second channel may be used.

Images are acquired at the user selected Frame Rate and Integration time at intervals determined by the user supplied triggers. For example: if a Frame Rate of 10 uS and and Integration time of 50 % is selected, the camera will complete one frame of 10 uS with 50 % Integration time for each trigger received. The interval between frames is arbitrary but should be kept small to avoid charge buildup. Although the camera dumps charge between frames, the dumping is not efficient enough to be used over long intervals. Note: If 100% integration time is selected in this mode, charge dumping does not occur while waiting for the next trigger, so the integration time is determined by the trigger rate.

Charge is dumped from the photosite while the camera is waiting for the next trigger. When the trigger is received, charge is integrated and shifted into the storage array.

In Multi Trigger Mode the user can select Frame Rate, Integration Time, Triggering configuration, User Strobes, and other options. The user must avoid overrunning the frame time of the camera. The frame time should be selected to be <= 90% of the trigger interval. At < 10uS per frame, the frame time should be selected to be <= 75% of the trigger interval.

The trigger uncertainty in this mode is 0 to 1 clock cycle (0 to 100 nS) regardless of frame rate. When the first trigger is received, the camera jumps to the Expose pattern and stops internal operation except for the system clock. When subsequent triggers are received, internal operation resumes on the next clock edge. When a frame is completed, internal operation is stopped again and the camera waits for the next trigger. This is repeated until all triggers have been received. No Pre-Trigger frames are kept in this mode.

Focus Mode

Focus mode is used for focusing the optics. Images are captured and displayed as rapidly as possible, without any storage of images to hard disk. Only 1 frame is displayed on the monitor, and it is captured after the trigger is received (Post-trigger).

In Focus Mode the user can select Frame Rate, Integration Time, Triggering configuration and other options. User Strobes are available only for the 1 frame which is displayed.

Computer Control and Software for the Ultra Fast Camera

The Camera's Control Computer is a Pentium class computer running Windows NT 4.0. The software's architecture allows the camera to be controlled remotely over any TCP/IP networking link and from almost any computer platform, whether it be a PC, Unix workstation, or Macintosh computer. Additionally, no software installation procedure is required in order to control the camera from a remote computer or workstation. The user only needs to establish a network connection (if running remotely) and then point a Web browser to the camera computer's network address. During operation, the user will be able to view (and print) directly from the Web browser images just acquired. The user can also view (and print) the camera's telemetry values or current camera setup.

Typically, for remote operation the camera's computer would be integrated into an existing TCP/IP network using standard Ethernet. However, since the software is written using the standard TCP/IP protocol one is not limited to an Ethernet connection, but can control the camera over any network which is TCP/IP based, whether it be a LAN, WAN, or the Internet.

Parasitic Exposure Problem

A problem with the first fast framing CCD design is what we have termed "parasitic exposure". Some small fraction of the photoelectrons created in the photodetector region of the pixel escape this region, disperse laterally and add to the photoelectron charge stored in the CCD charge storage cells that form the memory array portion of the pixel. In a given exposure, most all of the

photoelectrons generated during the frame interval are indeed channeled into the memory array or drain-dump via the proper charge transfer process designed into the device. However, when 32 exposures are made, the parasitic exposure of the oldest images stored in the array is the accumulation of ~32 such exposures. And the problem is made more acute by the fact that when the photodetector continues to be exposed to light following the high frame rate acquisition period, this parasitic exposure continues while the system is reading out the acquired images, a period that is several orders of magnitude longer than the acquisition time.

Overcoming this "parasitic exposure" problem by mechanically shuttering the light is difficult because the typical exposure time, a few microseconds, is several orders of magnitude shorter than mechanical shutters can provide.

Solutions or partial solutions are:

1. employ pulsed light sources for illumination, (pulsed laser, flash lamp)
2. use an electronic shutter,
3. reduce the lateral leakage of photoelectrons into the memory array by using spacing and/or potential barriers as part of the design.

Method 1 has been demonstrated to work well in experiments at Princeton University, and is a good choice if the target is not self-luminous.

An electronic shutter has been incorporated into the Ultra Fast Camera, as in method 2. This causes a decrease in sensitivity by about a factor 4 or less, and causes the spectral response to be limited to approximately 400 to 700 nm, but it significantly reduces the parasitic exposure by shuttering in <100 uS.

Method 3 has been implemented as part of the design of the CCD used in the Ultra Fast Camera, but does not eliminate the problem.

Conclusion

An Ultra Fast CCD Camera has been designed and built using a proprietary CCD designed by Princeton Scientific Instruments. Improvements were made over the first prototype, including a browser type user interface, easy selection of frame rate, and triggering options, and flexible operating modes. The camera provides for data acquisition at burst rates up to 1,000,000 frames per second, while readout is handled by a PC type computer, with image files stored in TIFF format. The ease of use, and operating flexibility, make the camera design viable for production and for new CCD formats based on the same charge storage concept.

Figure 3 is a photograph of the Camera Head and Electronics Chassis.

Appendix A is a printout of the On-line User Manual.

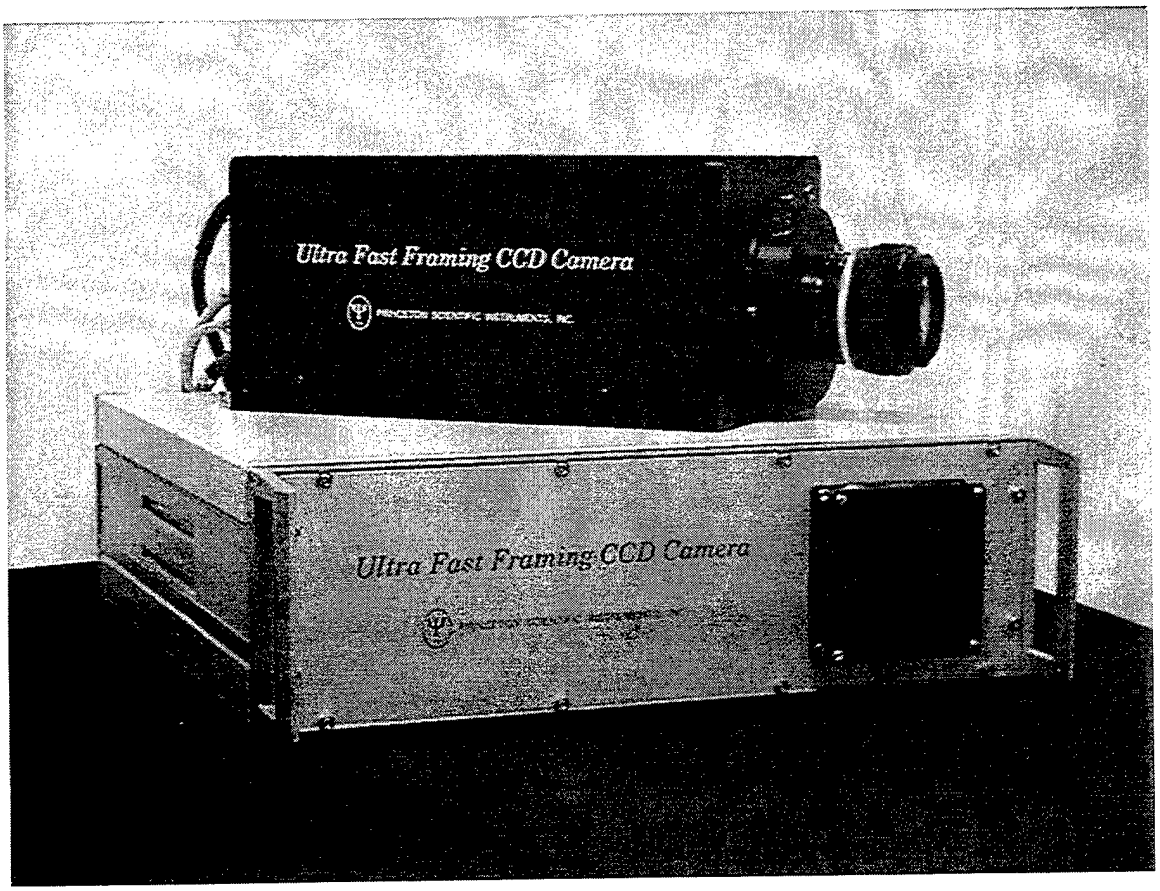


Figure 3. Photo of the Ultra Fast Camera Head and Electronics Chassis.

Appendix A

Ultra Fast Camera

Online User Manual

Princeton Scientific Instruments

Ultra Fast Camera Ver 1.1

Online User Manual

Table of Contents

General Description

Home Page

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The Data Acquisition Computer receives the digital data from the Control Chassis and stores it in memory. Due to the nature of the CCD image storage, 1 line of data contains pixels from 4 different frames. As data is read into memory, it is "unscrambled" so that pixels from the same frame are stored together and in order, forming an image raster. The images are also written to the hard disk as 32 separate files. The result of the readout is 32 frames in memory available for immediate display on a video monitor and 32 stored frames which can be down-loaded to a ZIP disk or can be accessed via an Ethernet link.

Operation

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Frame rate is user selected. The camera can capture images in an internally triggered mode upon command from the keyboard, or in an externally triggered mode. Before trigger, the camera runs with the shutter open in a continuous erase/expose mode. In this mode all frames in the storage area are continually over-written with new images while old images are dumped. When a trigger is received, the overwriting is stopped. The

result is that the most recent 32 frames are captured in the storage area. The shutters are closed and readout takes place as soon as the exposure is completed. The frames are given file names with a user supplied root name and consecutive numbers 1- 32 supplied automatically.

The computer monitor provides display of the images in memory. Images can be viewed sequentially in a "movie" mode, and images previously stored on the hard disk can be re-loaded into memory and displayed on the monitor. The digitized images can also be read by image processing software packages.

Table 1. Characteristics of CCD Image Sensor

Number of pixels 180 x 180 (90 x 180 active on S/N 01)

Pixel size 92 um x 92 um

Fill factor 34 %

Number of frame-storage CCD elements per pixel 3

Frame transfer CCD type 1260 x 1456

Readout format 3-phase CCD elements

Saturation signal 17,000 (A/D units)

Qmax 64,000 (electrons/pixel)

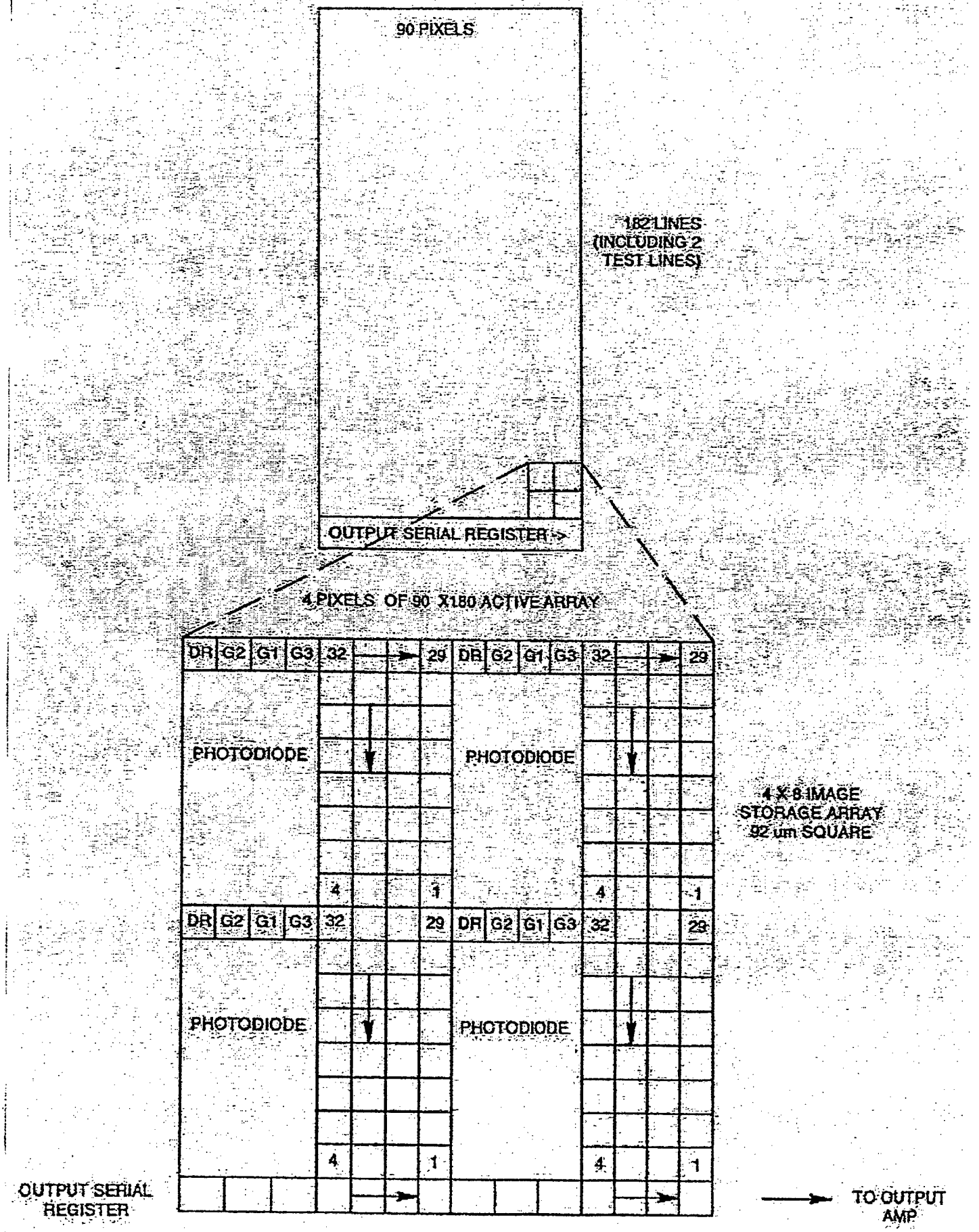
Readout noise 64.6 (rms electrons/pixel)

Dynamic range 1000:1

Maximum frame rate 1 x 10E6 frames/sec; (1 uS/frame)

Integration time 10 to 80 % and 100 % of frame time

FIGURE 1
PSI ULTRA FAST CAMERA CCD SCHEMATIC DIAGRAM



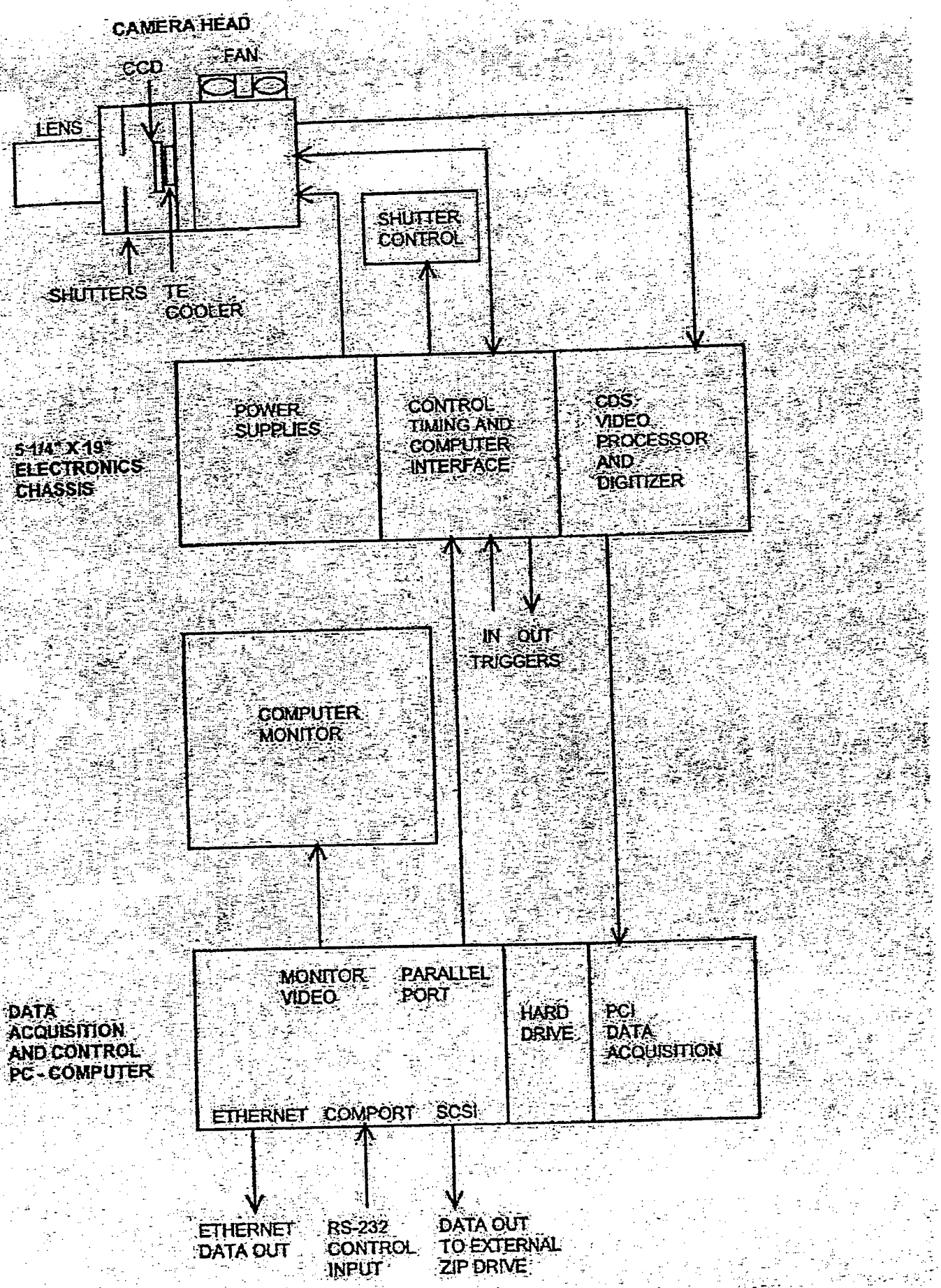


FIGURE 2. ULTRA FAST FRAMING CAMERA BLOCK DIAGRAM

Internal Operation

Home Page

RAM based operation

The camera control architecture is RAM based. That is, the operating waveforms for the CCD are loaded into RAMs on the control board prior to running the camera. This allows very flexible operation compared to fixed patterns stored in ROM, and also permits user control of timing signals which can be output during operation. Because the entire operating sequence is loaded into RAM prior to operation, there is no dead time required to write new data to the RAM. A large FPGA device on the Control Board handles the address generation for the RAMs and other digital control functions.

There are 2 groups of RAM.

VSRAM is the memory that contains the Vertical/Serial clocking patterns for the storage array. It also is the master control of system modes.

OSRAM is the memory that contains the Output Serial clocking patterns for the output serial register.

VSRAM is made up of VS Pattern RAM and VS State RAM.

VS Pattern RAM contains the clocking Patterns for moving charge in the storage array.

The same pattern can be repeated multiple times before moving on to the next pattern.

VS State RAM contains the counts (number of States) for each pattern to be repeated. It also contains control bits which define the system mode and enable bits for strobes.

OSRAM is made up of OS Pattern RAM and OS State RAM.

OS Pattern RAM contains the clocking Patterns for moving charge in the output serial register. The same pattern can be repeated multiple times before moving on to the next pattern.

OS State RAM contains the counts (number of States) for each pattern to be repeated.

Clocking Files

Clocking Files contain the values that are loaded into VSRAM and OSRAM.

The clocking files are developed from timing diagrams of the waveforms required for CCD operation.

Each waveform is assigned to a certain RAM output bit (2^0 through 2^15), so a timing diagram of 16 waveforms can be described with one Hexadecimal value for each time interval.

These Hex values are stored in the Clocking Files along with a number that represents how many times a particular value is repeated (repeat count).

In some cases, the repeat count is replaced with a control number. For example, -66 is a control number

which indicates the starting address of RAM.

Clock File List

A Clock File List is a list of clocking files in proper order, which will cause the RAMs to be loaded with the data necessary to operate in a particular way.

Operating Modes

Operating modes are determined by the Clock File List read in prior to operation. For example, there is a clock file list for PrePost, another for Multi, and another for Focus.

System Modes

When the RAMs have been loaded, the internal clocking of the FPGA is enabled and data is fetched from the RAMs. The operating sequence of the camera is divided into several system modes controlled by VS State RAM.

Wipe

During Wipe mode, the CCD storage array is wiped clean of charge. In this mode the VS Pattern causes a vertical shift, then stops and "hands off" to the OS Pattern which shifts a line from the OS register of the CCD. This is repeated 8 times to completely wipe the 8 row storage array. The CCD is clocked and charge is shifted through the array similar to readout, but the photosite is set up to dump charge. The output serial register is also clocked while being held in Reset, so charge is cleared from the register. This mode also provides the time required to open the manual shutter.

Fill

In Fill mode, the CCD storage array is filled with images using the same clocking pattern as Pre Expose. The OS Pattern is stopped, but the VS Pattern loops on a pattern of 1 vertical/serial shift and 3 serial shifts. This loop is repeated 8 times to completely fill the storage array. This ensures that the number of pre-trigger frames selected will be available before a trigger is accepted.

Pre Expose

During Pre Expose, the CCD storage array is continually overwritten with new images until a trigger is received. Pre Expose is a continuous Pre-trigger exposure loop. If Internal trigger has been selected, 1 loop will be completed, then the System Mode will jump to Expose. If External trigger has been selected, looping will go on indefinitely, and new frames will continuously overwrite old frames until a trigger is received, and the System Mode jumps to Expose.

Expose

Expose begins after a trigger is received.

In the PrePost operating mode, Expose begins after a trigger has been received and the clocking pattern for the current row has been finished. Thus there is an uncertainty of 0 to 4 frames in where the trigger occurs.

In the Multi-trigger operating mode, Expose begins after a first trigger has been received, without waiting

for the end of the current row. Subsequent triggers cause one new frame to be taken for each trigger with only one clock cycle uncertainty (100 nS with a 20 MHz Crystal).

In the Focus operating mode, Expose begins after a trigger has been received and the clocking pattern for the current row has been finished. Thus there is an uncertainty of 0 to 4 frames in where the trigger occurs. Only 1 frame is displayed in Focus mode.

Serial Prep

Serial Prep wipes the output serial register of accumulated charge to prepare for readout. It begins after the last frame has been exposed. In Serial Prep the OS Pattern runs and sweeps the OS Register of the CCD a number of times, then the System Mode changes to Readout.

Readout

During Readout, the images in the storage array are shifted into the output serial register, and read out one line at a time.

The readout occurs in the following sequence:

One Vertical Shift

Shifts all rows of images toward the output serial register - the row closest to the output serial register is loaded.

One Line Readout

The row loaded into the output serial register is shifted serially toward the output amplifier. The pixel at the output amplifier is read out using double correlated sampling. Serial shifting and pixel readout is repeated for the number of pixels per storage row times the number of columns on the CCD.

The above sequence is repeated for the number of storage rows per photosite times the number of rows on the CCD.

Done

Done means the readout and data acquisition are complete and the data files can be written.

Data files are written with the user supplied file name and the display is updated.

System Specifications

Home Page

Rear Panel I/O

Trigger Inputs

Trigger inputs are user selectable for BNC or Fiber Optic input, Trigger edge, and Gating.

Name	Type	Levels	Load
Trig 1	BNC	TTL	10K Ohms
Trig 1	ST Fiber Optic	10 - 150 uW	NA
Trig 2	BNC	TTL	10K Ohms
Trig 2	ST Fiber Optic	10 - 150 uW	NA

Trigger Outputs

Trigger Out occurs when external trigger conditions have been met after ~120 nS delay.

Ready goes high when the camera is waiting for a trigger, and can be used to gate or initiate an external trigger source.

Name	Type	Levels	Load
Trigger Out	BNC	TTL	>=50 Ohms
Ready	BNC	TTL	>=50 Ohms

Output Strobes

VSTB 1 is a positive pulse which occurs at the first half of user selected frames.

VSTB 2 is a positive pulse which occurs at the last half of user selected frames.

OSTB 1 is a 1 uS postive pulse which occurs at the start of Normal Pixel readout.

OSTB 2 is a 1 uS postive pulse which occurs at the start of Clamp Pixel readout.

Name	Type	Levels	Load
VSTB 1	BNC	TTL	>=50 Ohms
VSTB 2	BNC	TTL	>=50 Ohms
OSTB 1	BNC	TTL	>=50 Ohms
OSTB 2	BNC	TTL	>=50 Ohms

Outputs

Frame, Line, and Clock are sync signals related to data acquisition by the host computer.

D/A Video is a monitor point for one channel of 'scrambled' video output.

Name	Type	Levels	Load
Frame	BNC	TTL	>=50 Ohms
Line	BNC	TTL	>=50 Ohms
Clock	BNC	TTL	>=50 Ohms
D/A Vid	BNC	Analog	0 to 8.2V >=100 KOhms

Hardware Connections

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Main Components

Data Acquisition Computer and Monitor

Ultra Fast Camera Chassis

Ultra Fast Camera Head and Shutter Control Box

Required Cables

NAME	TYPE	CONNECTORS
Data Acquisition	25 Pair	62 Position High Density "D" Male
Head Clocks	25 Pair	44 Position High Density "D" Male
Head Power/TLM	25 Cond.	25 Position "D" Female
Camera Control	25 Cond.	25 Position "D" Male
Temp Control	11 Cond.	10 Position Circular Female
VID1	Triax	Concentric Triax
VID2	Triax	Concentric Triax
ISO 1 (Shutter Control)	Coax	BNC

Optional cables are those used for external trigger, user strobes, etc. as described in the System Specifications.

PrePost Trigger Mode Description

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PrePost Trigger Mode is the image acquisition mode in which the camera free runs in a continuous loop until triggered. While running in the contiuous Pre-trigger loop , new frames continually overwrite old frames. When the trigger is received, the camera will continue to run and acquire the user specified number of Post-trigger frames, then acquisition stops and readout begins.

The number of Post-trigger frames can vary from 0 to 4096 in multiples of 4. When the number is 0, all frames are acuired before the trigger during the Pre-trigger loop. When the number is from 4 to 28, the acquisition is divided between Pre-trigger and Post-trigger frames. When the number is 32 or more, all acquisition takes place after the trigger.

When the number of Post-trigger frames is greater than 32, the camera will delay acquisition after the trigger is received by a time equal to the number of frames greater than 32. For example: if the number of Post-trigger frames selected is 64, and the frame time is 10uSec, then the camera will delay for 32(extra frame times) x 10uSec = 320uSec before acquisition.

If External Trigger has been selected, and a trigger can not be supplied, then theCancel Button must be used to break out of the aquisition mode.

In PrePost Mode the user can select Frame Rate, Integration Time, Triggering configuration, User Strobes and other options.

The trigger uncertainty in this mode is 0 to 4 frames. When a trigger is received, the frames of the current row in the storage array are completed before jumping to the Expose pattern. This is necessary to avoid losing Pre-Trigger frames.

PrePost Trigger Mode Setup

To acquire images in the PrePost Trigger Mode:

Select "PrePost" from the Operating Mode pulldown list.

Click the "Camera" button to view the clock file, frame rate and trigger conditions at which the images will be acquired. The Frame Rate can be changed by clicking on the arrows to the right of the Frame Rate edit box. the second set of buttons to the right changes the Frame Rate by a factor of 10. To setup Trigger conditions, click the "Setup" button to launch the Trigger Setup dialog box.

Click the "Files" button to assign file names to the images which will be acquired.

Click the "Take Picture" button to start acquiring images. Images will be captured at the selected frame rate when trigger conditions are met. The 32 images will be stored in .TIF format with the previously selected file names.

Click the "Cancel" button to abort the acquisition.

Post Trigger Mode Description

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Post Trigger Mode is the image acquisition mode in which the camera free runs in a continuous loop until triggered. While running in the continuous Pre-trigger loop, charge is continually dumped preventing dark charge buildup. Pre-Trigger image acquisition is not available in this mode. When the trigger is received, the camera jumps to the Expose pattern and acquires the user specified number of Post-trigger frames, then acquisition stops and readout begins.

The number of Post-trigger frames can vary from 32 to 4096 in multiples of 4. When the number of Post-trigger frames is greater than 32, the camera will delay acquisition after the trigger is received by a time equal to the number of frames greater than 32. For example: if the number of Post-trigger frames selected is 64, and the frame time is 10uSec, then the camera will delay for 32(extra frame times) x 10uSec = 320uSec before acquisition.

If External Trigger has been selected, and a trigger can not be supplied, then theCancel Button must be used to break out of the aquisition mode.

In Post Mode the user can select Frame Rate, Integration Time, Triggering configuration, User Strobes and other options.

The trigger uncertainty in this mode is 0 to 4 substates (0 to .4 frames). When a trigger is received, the frames of the current row in the storage array are skipped and the camera jumps to the Expose pattern. No Pre-Trigger frames are kept in this mode.

Post Trigger Mode Setup

To acquire images in the Post Trigger Mode:

Select "Post" from the Operating Mode pulldown list.

Click the "Camera" button to view the clock file, frame rate and trigger conditions at which the images will be acquired. The Frame Rate can be changed by clicking on the arrows to the right of the Frame Rate edit box. the second set of buttons to the right changes the Frame Rate by a factor of 10. To setup Trigger conditions, click the "Setup" button to launch the Trigger Setup dialog box.

Click the "Files" button to assign file names to the images which will be acquired.

Click the "Take Picture" button to start acquiring images. Images will be captured at the selected frame rate when trigger conditions are met. The 32 images will be stored in .TIF format with the previously selected file names.

Click the "Cancel" button to abort the acquisition.

Multi TriggerMode Description

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Multi Trigger Mode is the image acquisition mode in which the camera free runs in a continuous loop until a first trigger is received, then waits for subsequent triggers for each of the 32 frames. While running in the continuous Pre-trigger loop, charge is continually dumped preventing dark charge buildup. Pre-trigger image acquisition is not available in this mode. When the first trigger is received, the camera jumps to the expose pattern and waits for a trigger for each frame. One frame is exposed for each trigger at the user specified frame rate and integration time.

All 33 triggers must be received (first trigger + 32 frame triggers), or the camera will not readout the images. If all 33 triggers can not be supplied then theCancel Button must be used to break out of the acquisition mode. The first trigger may be input on the same trigger channel as the 32 frame triggers, or a the second channel may be used.

Images are acquired at the user selected Frame Rate and Integration time at intervals determined by the user supplied triggers. For example: if a Frame Rate of 10 uS and and Integration time of 50 % is selected, the camera will complete one frame of 10 uS with 50 % Integration time for each trigger received. The interval between frames is arbitrary but should be kept small to avoid charge buildup. Although the camera dumps charge between frames, the dumping is not efficient enough to be used over long intervals. Note: If 100% integration time is selected in this mode, charge dumping does not occur while waiting for the next trigger, so the integration time is determined by the trigger rate.

Charge is dumped from the photosite while the camera is waiting for the next trigger. When the trigger is received, charge is integrated and shifted into the storage array.

In Multi Trigger Mode the user can select Frame Rate, Integration Time, Triggering configuration, User Strobes, and other options. The user must avoid overrunning the frame time of the camera. The frame time should be selected to be <= 90% of the trigger interval. At < 10uS per frame, the frame time should be selected to be <= 75% of the trigger interval.

The trigger uncertainty in this mode is 0 to 1 clock cycle (0 to 100 nS) regardless of frame rate. When the first trigger is received, the camera jumps to the Expose pattern and stops internal operation except for the system clock. When subsequent triggers are received, internal operation resumes on the next clock edge. When a frame is completed, internal operation is stopped again and the camera waits for the next trigger. This is repeated until all triggers have been received. No Pre-Trigger frames are kept in this mode.

Multi Trigger Mode Setup

To acquire images in the Multi Trigger Mode:

Select "Multi" from the Operating Mode pulldown list.

Click the "Camera" button to view the frame rate and trigger conditions at which the images will be acquired. The Frame Rate can be changed by clicking on the arrows to the right of the Frame Rate edit box. the second set of buttons to the right changes the Frame Rate by a factor of 10. To setup Trigger conditions, click the "Setup" button to launch the Trigger Setup dialog box.

Click the "Take Picture" button to start acquiring images. Images will be captured at the selected frame rate when trigger conditions are met. The 32 images will be stored in TIFF format with the previously selected file names.

Click the "Cancel" button to abort the acquisition.

Focus Mode Description

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Focus mode is used for focusing the optics. An image is captured and displayed as rapidly as possible, without any storage of images to hard disk. Only 1 frame is displayed on the monitor, and it is captured after the trigger is received (Post-trigger).

In Focus Mode the user can select Frame Rate, Integration Time, Triggering configuration and other options. User Strobes are available only for the 1 frame which is displayed.

Focus Mode Setup

To acquire images in the focus mode:

Select "Focus" from the Acquisition Mode pulldown list.

Click the "Camera" button to view the frame rate and trigger conditions at which the images will be acquired. To change the Frame Rate or setup Trigger conditions, click the "Setup" button and make the changes.

Click the "Take Picture" button to start acquiring images. Images will be continuously updated at approximately 4 second intervals. No images are stored on the hard disk in the Focus mode.

Click the "Cancel" button to stop acquiring images.

Main Operating Buttons

Take Picture Button

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The Take Picture button causes the following actions to occur in sequence:

1. Set up the camera hardware with the appropriate control files and control variables set in the various dialog boxes.
2. Prepare the data acquisition board in the host PC for the digitized images.
3. Run the camera clocking patterns and wait for the trigger events. If Internal Triggering is selected, then the camera is internally triggered and ignores external trigger inputs.
4. Wait for Imaging and Readout to the PC main memory to complete.
5. Write the browser compatible JPEG file.
6. Write the Image Processing Software compatible TIFF files to hard disk, if enabled by user.
7. Display the JPEG images in a mosaic format on the browser display frame.

Note: In Focus mode, no files are written to the hard disk, and only1 frame is displayed in the browser

Cancel Button

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The Cancel button cancels the ongoing image acquisition sequence. If images are being acquired in Focus Mode, this button must be used to stop. If External trigger has been selected, and triggers can not be provided, or less than 33 can be provided in Multi trigger mode, then the Cancel button must be used to break out of the acquisition mode. See Trigger Setup.

Camera... Button

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The Camera... Button launches the appropriate camera setup dialog box as defined by the current operating mode.

Main Operating Buttons

Take Picture Button

Home Page

The Take Picture button causes the following actions to occur in sequence:

1. Set up the camera hardware with the appropriate control files and control variables set in the various dialog boxes.
2. Prepare the data acquisition board in the host PC for the digitized images.
3. Run the camera clocking patterns and wait for the trigger events. If Internal Triggering is selected, then the camera is internally triggered and ignores external trigger inputs.
4. Wait for Imaging and Readout to the PC main memory to complete.
5. Write the browser compatible JPEG file.
6. Write the Image Processing Software compatible TIFF files to hard disk, if enabled by user.
7. Display the JPEG images in a mosaic format on the browser display frame.

Note: In Focus mode, no files are written to the hard disk, and only1 frame is displayed in the browser

Cancel Button

Home Page

The Cancel button cancels the ongoing image acquisition sequence. If images are being acquired in Focus Mode, this button must be used to stop. If External trigger has been selected, and triggers can not be provided, or less than 33 can be provided in Multi trigger mode, then the Cancel button must be used to break out of the acquisition mode. See Trigger Setup.

Camera... Button

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The Camera... Button launches the appropriate camera setup dialog box as defined by the current operating mode.

- PrePost Trigger Mode - The user selects Frame Rate, Integration Time, Trigger configuration, number of post trigger frames, normal or simulated video, and can launch the Output Strobes and Trigger Setup dialog boxes. One internal or external trigger is required for this mode.

- Post Trigger Mode - The user selects Frame Rate, Integration Time, Trigger configuration, number of post trigger frames (>=32), normal or simulated video, and can launch the Output Strobes and Trigger Setup dialog boxes. One internal or external trigger is required for this mode.

- Multi Trigger Mode - The user selects Frame Rate, Integration Time, normal or simulated video, and can launch the Output Strobes and Trigger Setup dialog boxes. 33 external triggers are required for this mode. The first trigger causes a jump to the Expose clocking pattern and waits for subsequent triggers. Each trigger causes a new frame to be stored, until all 32 frames are completed.

- Focus Mode - The user selects Frame Rate, Integration Time, Trigger configuration, normal or simulated video, and can launch the Trigger Setup dialog box. One internal or external trigger is required for this mode. No files are stored in this mode, it is display only.

Files... Button

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The Files... button launches a dialog box which allows the user to choose a file name and destination folder for the image files which are created upon readout of the CCD. The selected name will be used to create a folder of the same name which will contain 32 image files in .TIF format. The files will be named Frame01 through Frame32. For example, if the user supplies the name TEST, a folder named TEST will be created, and it will contain files labeled Frame01.TIF through Frame32.TIF. File names should be kept to 6 characters or less if the image processing software to be used only handles names of 8 characters.

The Refresh button displays a list of previously stored images which may be selected and then reloaded for display by clicking the Read Image button.

Display... Button

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The Display... button launches a dialog box which allows the user to adjust the contrast of the image displayed in the browser.

A "movie" of the currently viewed images can be started and stopped from within this dialog box.

Telemetry Button

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The Telemetry button is used to sample and display a table of monitored voltages from the chassis and camera head, and also the temperature of the CCD.

Diagnostics... Button

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The Diagnostics... button lauches a dialog box which can be used to continually monitor a particular Telemetry point. This is useful during setup of CCD voltages and also to monitor temperature after turn-on. The Telemetry Address must be used to choose the particular point to be monitored. Clicking the Help button within this dialog box brings up the list of Telemetry Addresses available.

The Self Test button within this dialog box, executes a test of the hardware including power supplies and RAMs, and displays the Pass/Fail results in about 40 seconds.

Help... Button

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The Help... button lauches this on-line user manual.

Acquire Images

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Real images can be acquired in 4 different modes, PrePost Trigger Mode, Post Trigger Mode, Multi Trigger Mode, and Focus Mode.

PrePost Mode captures 32 images with a single trigger at the user defined frame rate and trigger conditions and stores the images on the hard disk as 32 separate files in .TIF format.

Trigger uncertainty in this mode is 0 to 4 frames. See PrePost Trigger Mode .

Post Mode captures 32 images with a single trigger at the user defined frame rate and trigger conditions and stores the images on the hard disk as 32 separate files in .TIF format.

Trigger uncertainty in this mode is 0 to 4 substates. See Post Trigger Mode .

Multi Trigger Mode captures 32 images by individual triggers at the user defined frame rate and trigger conditions and stores the images on the hard disk as 32 separate files in .TIF format.

Trigger uncertainty in this mode is 0 to 100 nS. See Multi Trigger Mode .

In each of the above modes, a mosaic of 32 frames is displayed in the Browser after readout.

Focus Mode continuously updates the image shown on the monitor as rapidly as possible. No images are stored to the hard disk in this mode. See Focus Mode.

A simulated image (a bar pattern) can also be acquired for test purposes in any of the modes by enabling Simulated Video in the Camera Setup dialog box.

Rate Setup

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Click the "Camera" button to view the clock file, frame rate and trigger conditions at which the images will be acquired. To change the Frame Rate:

Use the arrows to increase or decrease the frame time. The second set of arrows to the right steps the frame time by a factor of 10. The frame rate is displayed below the frame time.

The Expose Rate is determined by two cacaded 8 bit rate generators. The first (Pre-Rate) pre-scales the rate to the second (Rate) generator. The total division of the clock rate is the product of the Pre-Rate and Rate values. For maximum resolution, the Pre-Rate generator is run at the maximum possible rate which will still allow the Rate generator to achieve the correct division of the clock rate. The longest frame time that can be obtained is the crystal oscillator period x 20 x 65536; i.e. 50 nSec x 20 x 65536 = 65.5 mSec or 15 Hz.

The Readout Rate is a fixed rate for low noise operation.

Trigger Setup

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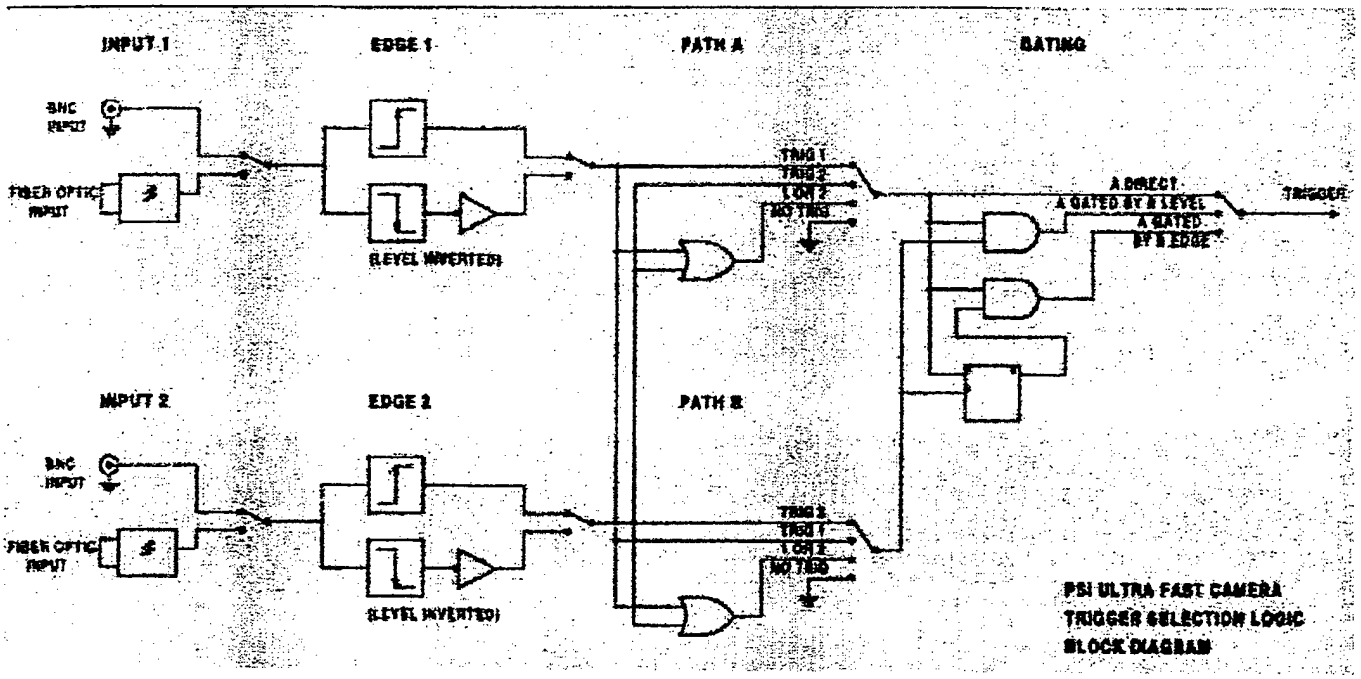

Input 1 and 2

Trigger Inputs 1 and 2 may be individually selected to come from either the BNC connectors or the Fiber Optic connectors on the rear panel.

BNC inputs: TTL/CMOS

F.O. inputs 10 - 150 uW

Note: Trigger inputs from the Fiber Optic connectors are AC coupled, and should be pulsed a few times after the fiber is connected to insure that the output state will agree with the input. Optical trigger pulses should have a fast rise time (<10nS), but there are no duty cycle requirements because the receiver output is latched to its last valid state.

Edge

The Trigger Edge for trigger inputs 1 and 2 may be individually selected to be either the rising or the falling edge.

Path A and B

The trigger inputs selected for Path A may be Trigger 1, Trigger 2, Trigger 1 logical ORed with Trigger 2, or No Trigger.

The trigger inputs selected for Path B may be Trigger 2, Trigger 1, Trigger 1 logical ORed with Trigger 2, or No Trigger.

Gating

The trigger signal routed to Path A may be used directly as the trigger, or the trigger signal on Path B may be used to gate the trigger signal on Path A. The Gating may be selected as either level sensitive, or edge sensitive. For example, the following trigger setup configuration:

Input1	Edge	Path A	Gating
BNC Trig1	Rising	Trig1	A Gated by B Edge
Input2	Edge	Path B	
BNC Trig2	Falling	Trig2	

will produce a trigger on the rising edge of BNC Trig1 after a falling edge has been received on BNC Trig2.

Trigger Out: 50 ohm source. Output >= 4V open circuit; >= 2V into 50 ohms.

User Output Strobes

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User output strobes are outputs from the camera which can be selected to occur at the end of FILL, during PRE EXPOSE, and during EXPOSE. They can be used to set up external events such as triggering a light source.

VSTB1 and VSTB2 are positive outputs which occur for each user selected frame. VSTB1 occurs in the first half of the frame and VSTB2 occurs in the last half. OSTB1 and OSTB2 are outputs which occur during READOUT. OSTB1 is a 1uS positive pulse which occurs at the start of Normal Pixels. OSTB2 is a 1uS positive pulse which occurs at the start of Clamp Pixels.

The user output strobes dialog box is accessed by clicking on the Camera... button, then the Output Strobes button, then the button for either VSTB1 or VSTB2.

To define where strobes will occur, click the boxes next to FILL, and PRE EXPOSE, and click the boxes next to the frame numbers in the edit box for EXPOSE. Frame numbers refer to EXPOSE frames (i.e. Post-Trigger frames) since Pre-Trigger frames are overwritten.

VSTB1 and VSTB2 are always enabled during FOCUS, for the 1 EXPOSE frame which is displayed.

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